



LITTLECOTT MILL

HYDRO-THERMOGEOLOGICAL APPRAISAL

MARCH 2026

PROJECT NO. 25261168

B. A. Hydro Solutions Limited
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HYDRO-THERMOGEOLOGICAL APPRAISAL

**Littlecott Mill
Enford Pewsey
Wiltshire
SN9 6AW**

Report researched and produced by B. A. Hydro Solutions Limited (BAHS Ltd) on the instruction of Fleming Architects Ltd.

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EXECUTIVE SUMMARY

This Appraisal was carried out to understand the ground conditions at Littlecott Mill and to assess whether a ground source heating (GSH) system can be safely and effectively installed. The study looked at geology, groundwater, environmental factors, and design considerations to ensure the proposed system is low-risk and sustainable.

Key Points:

Low Environmental Risk: The very shallow ground [near the surface] is generally dry and stable, and there is no evidence of contamination. Even if unexpected contamination is found during works, it will be managed immediately. This means the risk to the environment from drilling and installation is very low.

Groundwater Quantity & Quality: the proposed closed loop boreholes would be drilled to 120 metres depth passing through Chalk and the Upper Greensand, all of which are already in hydraulic continuity. Grouting of the boreholes would maintain any stratification that may be present. Grout would contain and seal the boreholes, offering protection against leakage of fluids [food grade antifreeze] which is very uncommon amongst the many thousands of such systems installed globally. The boreholes represent narrow columns through the ground (c 150mm diameter) and thus cannot have any impact on groundwater movement as they represent such a small proportion of the ground through which they pass.

Ground/Groundwater Temperature: The system is designed to access sufficient ground via the closed loop boreholes to be sustainable with ground temperatures recovering annually. Ground temperatures would drop to c.5 degrees centigrade in the natural ground immediately around the boreholes, reaching natural ground temperatures at a distance of 3 to 6 metres from the boreholes. Solar thermal recharge to the ground around the boreholes will replenish the warmth removed on an annual basis; there would be no thermal influence off site.

Soil and Habitat Disruption: The proposed drilling works are expected to result in only minimal and tightly contained disturbance to soil and local habitats, as each borehole requires only a very small footprint (approximately 150 mm in diameter) and all activity is restricted to the immediate drilling area. During installation, drilling muds and cuttings are carefully managed to prevent any release into the surrounding environment, with all arisings contained within one to two metres of the hole before being fully removed and the ground reinstated.

Once the ground loops are installed, the boreholes are sealed with low-permeability grout, ensuring the system is isolated from the surrounding soil and groundwater and preventing any future leaks or ecological impact. Because the sealed boreholes represent an extremely small proportion of the geological mass through which groundwater moves and are located away from sensitive features such as the River Avon, the scheme will have no measurable effect on groundwater-dependent habitats or wider ecosystems both during construction and throughout long-term operation.

Noise and Vibration: The drilling operations are expected to generate only low levels of noise and vibration, comparable to those produced by a heavy goods vehicle or excavator working on site, with most noise arising from the rig operating at idle rather than during active drilling. In the firm, but not excessively hard, ground expected at the site, the equipment will not struggle, meaning noise peaks will be minimal and short-lived. Vibration dissipates extremely quickly through the subsurface, with only very minor vibration detectable within a few metres of the rig and none measurable beyond approximately 5 to 10 metres, ensuring no disturbance or risk of damage to buildings, residents, or the surrounding environment. Overall, both noise and vibration impacts are assessed as low, short-term, and fully manageable using standard best-practice drilling methods.

Land Subsidence: The risk of land subsidence resulting from the proposed drilling works is assessed as very low, as the boreholes are narrow (150 mm diameter), remove only the minimal material required, and do not create voids or undermine surrounding

strata. Temporary casing stabilises the upper, weaker, horizons during drilling, after which each borehole is fully sealed with low-permeability grout, restoring ground strength and preventing any future migration of soil or groundwater.

Groundwater levels lie below ground across all relevant aquifers, eliminating the risk of artesian pressures, and because the closed-loop system does not abstract or inject water, it does not alter groundwater pathways or pressures. Once installed, the grouted borehole forms a stable, solid column with no potential for erosion or void development, and the system's thermal effects remain confined within a few metres of each borehole and recover annually, ensuring no long-term or cumulative change to ground conditions.

System Design and Safety: The design includes multiple safeguards:

- Boreholes will be sealed and reinforced to prevent leaks.
- Headworks (the top part of the borehole) will be built to withstand pressure and prevent any water ingress during floods.
- All construction will follow strict industry standards and environmental regulations.

Thermal Performance: The ground beneath the site has good heat storage and transfer properties, making it suitable for a GSH&C system. This means the system will operate efficiently and provide long-term energy savings.

Overall Conclusion: The proposed ground source heating system is considered low risk from both environmental and technical perspectives. Potential risks are well understood and will be managed through proven engineering solutions. The project can proceed with confidence that it will deliver sustainable heating without harming the environment or creating future hazards.

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GLOSSARY OF TERMS

BAHS	B. A. Hydro Solutions Limited
µg/kg	Micrograms per kilogram
µg/l	Micrograms per litre
bgl	Below ground level
BGS	British Geological Survey
BH	Borehole
CA	Coal Authority (renamed the Mining Remediation Authority (MRA))
CAMS	Catchment Abstraction Management Strategy
DWI	Drinking Water Inspectorate
DWS	Drinking Water Standard
EA	Environment Agency
EHO	Environmental Health Officer
GP3	Groundwater Protection Policy
GSH/C	Ground Source Heating/Cooling
ha	Hectare
HSE	Health and Safety Executive
HGA	Hydrogeological Assessment
HTGA	Hydro-Thermogeological Assessment
LA	Local Authority
m	Metres
m ² /day	Square metres per day
m ³ /day	Cubic metres per day
maOD	metres above Ordnance datum
mg/kg	Milligrams per kilogram
mg/l	Milligrams per litre
MRA	Mining Remediation Authority (MRA), formerly known as the Coal Authority (CA)
NE	Natural England
NGR	National Grid Reference
NRW	Natural Resources Wales
PWL	Pumped Water Level
RWL	Rest Water Level
s	Drawdown in metres
SEPA	Scottish Environment Protection Agency
SPZ	Source Protection Zone
SSSI	Site of Special Scientific Interest
SVC	Volumetric Heat Capacity
T	Transmissivity
TGA	Thermogeological Assessment
UKAS	United Kingdom Accreditation Service
UXO	Unexploded Ordnance
λ	Thermal Conductivity

1 Introduction

B. A. Hydro Solutions Ltd. (BAHS) has been commissioned to complete a Hydro-Thermogeological Appraisal of conditions present at the following site with a view to developing a new ground source heating system at the location.

This Appraisal considers the hydrogeological and thermogeological characteristics of the ground beneath and surrounding the site. The geological and thermal properties reported are for use in developing a closed loop collector array design to sustain a ground source heating/cooling system. The hydrogeological setting is conceptualised so that the ground source heating/cooling design can avoid and mitigate for associated issues.

The site location is illustrated in the following figure; for the purpose of considering geological strata and depths to each stratum, a mean site elevation has been adopted throughout this report, as listed below:

Site Address:	Littlecott Mill	
	Enford Pewsey	
	Wiltshire	
Postcode:	SN9 6AW	
Drill position NGR:	SU 14243 51747	
Elevation adopted:	85	maOD

Table 1: Site details

2 Objectives

This Assessment seeks to fulfil the following objectives:

- Confirm the geological sequence.
- Define the hydrogeological setting.
- Consider where groundwater is present.
- Consider the variability of groundwater conditions present.
- Consider the likely quality of groundwater present.
- Produce a hydrogeological risk assessment.
- Report the regulatory conditions applicable.
- Quantify the thermal properties of the ground present.
- Provide bulk thermal values for different drilling depths.
- Identify potential drilling & geological hazard that may be encountered.
- Produce a concept design risk assessment.
- Provide a thermogeological summary for the ground beneath the site.

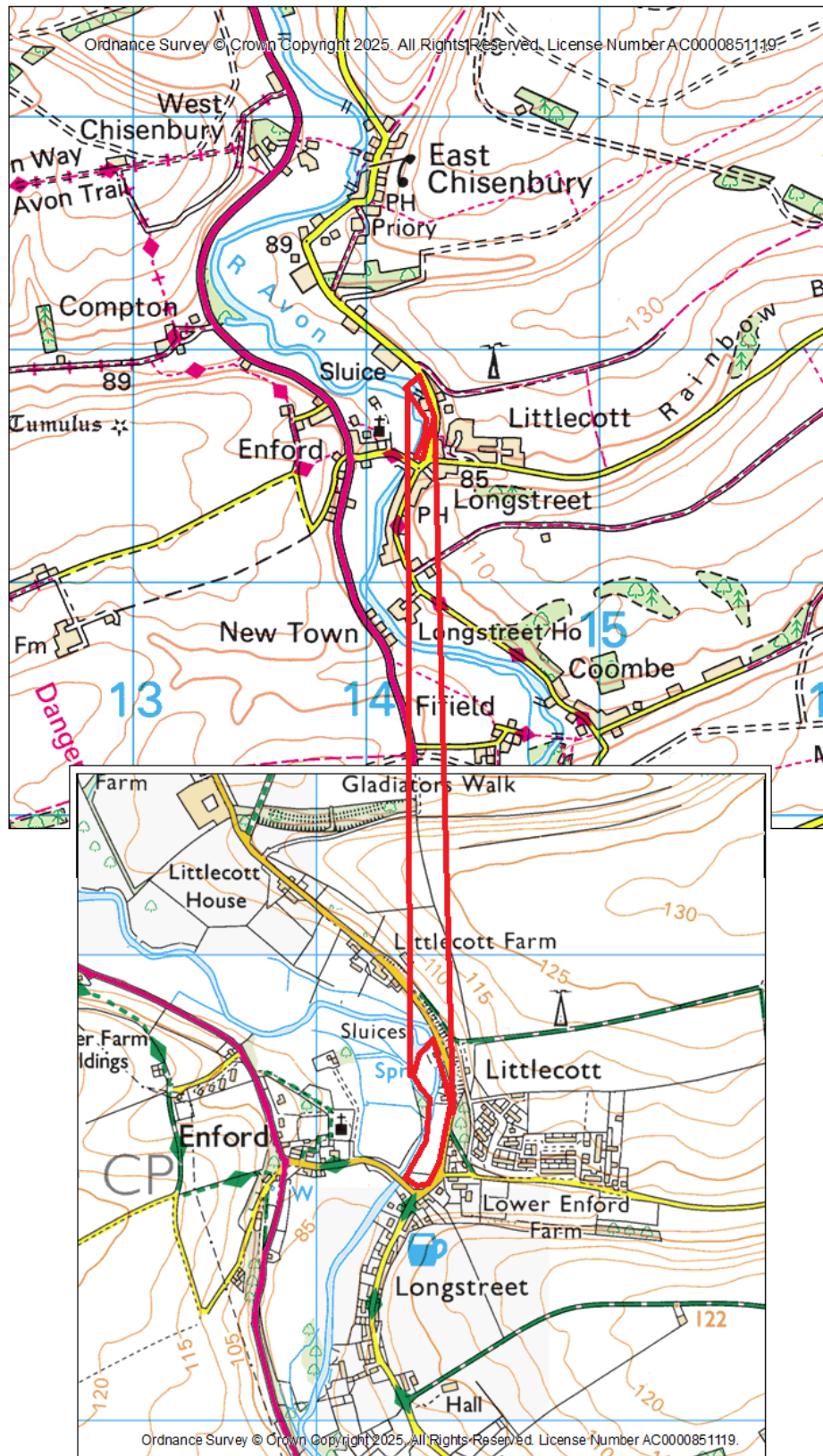


Figure 1: Location Map

3 Geological Setting

3.1 Geology

The following discussion of the geology beneath the site is based on a site-specific literature review and historical borehole records that have been obtained for the purpose of predicting the geological unit thickness, nature and depths. As geological units are not laterally continuous, vary in thickness and are not homogeneous, the predicted thickness and depths may differ slightly if or when proved by drilling.

It is recommended that during drilling B. A. Hydro Solutions Limited are consulted in order to compare the confirmed geology with that anticipated in order to refine the thermal properties reported. The geology and thicknesses reported are based on the assumption that the borehole(s) is drilled at the National Grid Reference (NGR) listed in Table 1 from the elevation stated. If the drill position changes the findings of the Assessment will need to be updated.

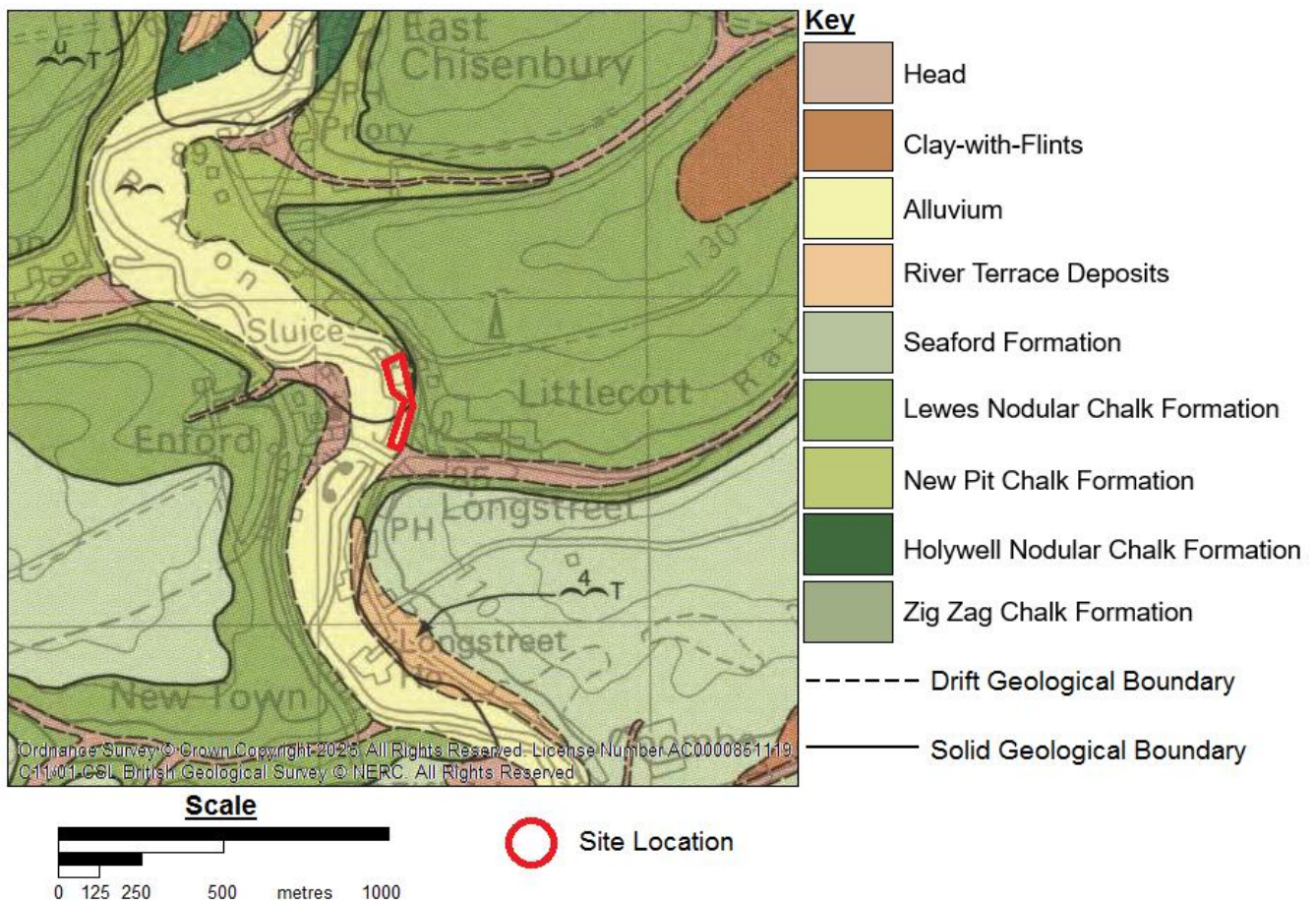


Figure 2: Geological Map

The geology mapped at ground level across the local area is illustrated in Figure 2; the location of the site is outlined in red, the following table summarises the strata present, their names, lithological nature and the anticipated thicknesses of each unit.

Geological Group	Geological Formation	Lithological Nature	Anticipated Thickness (metres)
-	-	Soil and/or Worked Ground and/or Made Ground	<2
-	Alluvium	Clays, silts, sands and gravels	2 to 4
White Chalk Subgroup	New Pit & Holywell Nodular Chalk Formations	Chalk & flints	31 to 34
Grey Chalk Sub-Group	Zig Zag Chalk Formation	Mudstones with limestones, siltstones and ironstones	25 to 27
Grey Chalk Sub-Group	West Melbury Marly Chalk Formation	Mudstones with limestones, siltstones and ironstones	44 to 47
Selborne Group	Upper Greensand Formation	Mudstones with limestones, siltstones and ironstones	42 to 48
Selborne Group	Gault Formation	Clays and Mudstones	25 to 45
Selborne Group	Lower Greensand Formation	Silty sands and sandstones	1 to 12
Portland Group	Portland Group	Sand, silt & clay	10 to 15
Ancholme Group	Kimmeridge Clay Formation	Mudstones and siltstones	100 to 120

Table 2: Summary of Geological Sequence

3.2 Structure

The main geological structures present and affecting the ground beneath the site are listed below. The tectonic events and the sequences leading to the resulting structures are not considered by this Assessment as such detail does not affect the conclusions drawn by this study.

- Faults in the local area are anticipated to affect the geological sequence or the presence/abundance of groundwater beneath the site.
- The strata considered by this Assessment have experienced minor tectonic deformation since their deposition, they have been gently folded/tilted and faulted.
- The strata dip at 1 to 2 degrees to the north-west.

4 Lithological Characterisation

4.1 Soil & Drift

4.1.1 Soil

All sites are underlain by some form of soil, worked ground, made ground or a combination of the above. This Assessment does not seek to characterise the nature of this layer as it is normally relatively thin and has a very limited influence on the thermal properties of the ground. Where sites are underlain by known or possible contamination, appropriate professional advice should be sought. If the ground is contaminated the approach to drilling and completion of closed loop boreholes would need to reflect the conditions present.

As a precautionary approach, it should be assumed when designing a new abstraction borehole, that the soil could be liable to collapse, and that temporary casing would be needed through the soil and drift deposits present beneath. Soils and the first 10 metres below ground level [depending on ground conditions] should be sealed out of new boreholes on completion in order to form a reliable sanitary seal.

4.1.2 Drift

Alluvium at this location comprises unconsolidated, geologically recent fluvial sediments (clay, silt, sand, and gravel) deposited by running water in streambeds, floodplains, or alluvial fans. Typically poorly sorted to semi-sorted, it may include occasional organic-rich layers and variable grain sizes from fine clay to coarse pebbles. At the site, this alluvial unit ranges between 2 and 4 metres in thickness, forming a continuous cover of fluvial material over the underlying substratum.

4.2 New Pit & Holywell Nodular Chalk Formations

The rock head beneath this site is formed by the New Pit & Holywell Nodular Chalk Formations which is likely to be weathered to a depth of 5 to 10 metres below rock head. Weathering, erosion and exposure will have reduced the strength of the ground resulting in it becoming weaker, less able to stand without temporary support and liable to collapse when drilled.

The New Pit Chalk Formation is firm and smooth-textured and lacks the nodularity and abundant shell remains of the underlying Holywell Nodular Chalk, but, in its upper section, bands of nodular flints do appear. The New Pit Chalk Formation is generally blocky in appearance, and is firm to hard, with

increasing numbers of marl seams, which are slightly more noticeable than in the Holywell Nodular Chalk Formation below. Several thick marl beds, more than 0.1 metre thick, occur in the upper part of the New Pit Chalk. Flint seams occur towards the Formation base, with these most noticeable over geological structural highs, and towards the margins of the Chalk outcrop.

The Holywell Nodular Chalk Formation tends to be hard, nodular and distinctively shell-rich. It contains regularly developed thin beds of marl throughout and an interval with several beds of greenish-grey marl at the base, up to several metres thick, named the Plenus Marls Member. A known hard-band within the Holywell unit occurs just above the Plenus Marls, and is named the Melbourn Rock. This is a very hard thin layer of around 3 metres, made up of blocky fractured chalk and often with nodular chalk. It is much more resistant than the surrounding chalk.

When drilling through the New Pit & Holywell Nodular Chalk Formations, one can expect a minimum thickness of 31 metres, potentially reaching up to 34 metres. Below a weathered upper surface, the hardness and competence of the formation increase, leading to stable ground conditions once drilled. The top of the Chalk may be weathered and degraded, forming Putty Chalk, a white clayey material with less weathered chalk blocks. As drilling depth increases, the clayey nature diminishes until reaching firm natural chalk. Although no encounters are anticipated at this location, it is possible to come across such formations. It is important to note that drilling through this unit may result in high drilling fluid losses.

4.3 Zig Zag Chalk Formation

The Zig Zag Chalk Formation forms the topmost unit of the Grey Chalk Subgroup and is generally firm but blocky, with a pale grey appearance; the lower portion is characterised by regular alternations between marl bands and marly chinks within firm white chalk. Marker beds of silt rich, gritty material can be found within this sequence too.

The base of the Zig Zag Chalk Formation layer is a hardground called the Totternhoe Stone Member. The Totternhoe Stone Member is typically brown-grey colour, formed of fine grained, hard calcite cemented chalk material. The layer may be referred to as being “sandy” due to the coarse fossil fragments found within it, rather than actual sand grains being found. This unit is thin to thickly bedded and can contain hard pellets of dark brown phosphatic cementations within the softer chalk in places; the pellets are up to a few centimetres across.

Totternhoe Stone may be difficult to visually distinguish from the overlying chalk of the Zig Zag Chalk Formation, the Member is noticeably harder than that above, and slightly coarser grained. The lower boundary of the Totternhoe Stone Member is often indistinct.

When drilling through the Zig Zag Chalk Formation, which has a minimum thickness of 25 metres up to 27 metres, one can expect hard conditions. Once drilled, the ground will normally stand without support; however, this unit is often associated with a moderate to high level of loss of drilling fluids.

4.4 *West Melbury Marly Chalk Formation*

The West Melbury Marly Chalk Formation underlies the Zig Zag Chalk, apart from where it is known to be absent over the Mid-Dorset Swell. It is typified by its creamy, buff or grey colour chalk. This chalk is soft, with marly layers throughout and interbeds of hard grey limestone, generally alternating throughout the Formation. The upper boundary with the overlying Zig Zag Chalk Formation is noted by the change from chalk with marls above, to the well-defined alternating limestone and marl bands of the West Melbury Marly Chalk below.

The lower boundary of the West Melbury Marly Chalk Formation is an unconformable erosional surface. This surface is known as the Glauconitic Marl Member in most of the Southern Province, the Melbury Sandstone Member in the Western Southern Province and the Cambridge Greensand Member in the immediate Cambridge area of the Transitional Province reaching into East Anglia.

When drilling through the West Melbury Marly Chalk Formation, which has a minimum thickness of 44 metres and can reach up to 47 metres, one can expect firm conditions. Once drilled, the ground will normally stand without support; however, it is important to note that some drilling flush can be lost during the drilling process.

4.5 *Upper Greensand Formation*

The composition of the Upper Greensand Formation varies from site to site, but typically consists of interbedded fine sand and sandstones. Sometimes the arenaceous sediments are so fine grained they form silt or silty sands/sandstones. The sands may also have a calcareous or clayey matrix and often contain shell fragments.

The sandstones of the Upper Greensand are commonly glauconitic and have a high iron content. The glauconite and iron minerals when freshly exposed are green in colour, giving the Upper Greensands their name. The Upper Greensand quickly weathers to red brown upon exposure. Bioturbation and ripple marks, made at the time of deposition, may still be found within the strata. Shells, particularly those of bivalves, mark out bedding planes.

When drilling through the Upper Greensand Formation, which has a minimum thickness of 42 metres but can reach up to 48 metres, expect weakly consolidated and very unstable ground that is prone to collapsing. To stabilise the hole, temporary casing or carefully managed drill muds will likely be necessary. There is a high likelihood of encountering running sands in this unit, and some drilling flush may be lost during the drilling process.

4.6 Gault Formation

The Gault Formation consists chiefly of dark grey, clayey mudstones that are often sandy, glauconitic and sometimes even micaceous. With increasing depth from the top of the unit a distinction between softer clay and harder mudstone horizons should become apparent as distinct interbedding. Towards the base of the Formation, there are thicker, harder layers of mudstone, gritty mudstones, and phosphatic beds.

When drilling through the Gault Formation, which has a minimum thickness of 25 metres and can reach up to 45 metres, well-consolidated conditions are typically encountered. Normally, drilling through this unit results in little loss of flush.

4.7 Lower Greensand Formation

The Lower Greensand, also known as the Woburn Sands Formation, is comprised of sandstones and loose sands of marine origin. The sand and sandstones are formed of rounded quartz grains which range from fine to coarse in size. The unit contains some silty and clayey layers which locally develop into Fullers Earth.

The sediments are cross bedded yellow to brown in colour with some pebble and phosphatic nodules towards the base of the unit. Overall, it tends to have a moderate glauconitic, iron and phosphorous content. The unit has an unconformable lower and upper boundary indicating it was deposited following

a period of erosion of older strata and itself was partially eroded before younger sediments were laid on top.

The upper part of the Formation is sometimes found to have layers of carstone, mudstone, marls and occasional clays. This layer, sometimes known as the Junction Beds, may be a partial re-working of weathered Lower Greensand prior to or during the deposition of the younger strata.

When drilling through the Lower Greensand Formation, which can range from 1 metre to up to 12 metres in thickness, weakly consolidated and very unstable ground conditions are to be expected, making it prone to collapsing. To stabilise the hole, temporary casing or carefully managed drill muds will likely be necessary. There is also a high likelihood of encountering running sands within this unit, leading to potential loss of drilling flush during the drilling process.

4.8 *Portland Group*

The Poole Formation is comprised of four depositional sequences with erosional bases and surfaces. The sequence is as follows; lower sand units overlain by an upper clay unit. The Sand units usually have a pebbly base and are medium to coarse grained with planar cross-bedding and water escape structures. Generally, they coarsen westwards with gravels being developed in places with large proportions of quartz pebbles. The Clay units are kaolinitic with silt which is usually multicoloured and interbedded with organic rich clay layers and laminated clays. The kaolinitic clays tend to be dominant around Wareham but the laminated clays are more seen in the Bournemouth-Poole area.

The upper boundary of this Formation is marked by the erosional contact between clays and silts of the Parkstone Clay Member and Branksome Sand Formation.

The lower boundary is defined by the coarse-grained sands of the Poole Formation overlying the sands and clays of the London Clay Formation. The Poole Formation appears to thin towards the North and East of Poole itself, into the higher beds of the London Clay.

When drilling through the Portland Group, some drilling flush can be lost due to the presence of discrete layers that could produce running sands. This geological unit has a minimum thickness of 10 metres, with the potential to reach up to 15 metres. The formation is hard, indicating that drilling may require more effort and specialised equipment to penetrate through the rock.

4.9 *Kimmeridge Clay Formation*

The Kimmeridge Clay Formation is the uppermost geological horizon of the Ancholme Group and outcrops across the country, from Yorkshire to Dorset. The Kimmeridge Clay is typically seen as a grey to brown coloured unit dominated by mudstones. The Formation consists of small-scale cyclic bands of bituminous, calcareous, silty and sandy mudstones. There are also many thin siltstone horizons and cementstone beds inter-bedded with the mudstones. Discrete sandstone and thin conglomerate layers occur regularly through the unit and are locally named as Member horizons, as they are not laterally continuous, are rarely well mapped and represent very small sections of the lithological sequence, they are not documented or named individually within this Assessment.

When drilling through the Kimmeridge Clay Formation, which has a minimum thickness of 100 metres and can reach up to 120 metres, one can expect firm conditions. Normally drilling through this unit results in little loss of flush.

5 Hydrology and Hydrogeology

5.1 Hydrology

The Environment Agency's flood designation for the site is summarised below, this Assessment is not, and cannot be used as part of, a flood risk assessment.

Flood risk from River or Sea:	High Risk
Description of Risk:	High risk means that this area has a chance of flooding of greater than 3.3% each year. This takes into account the effect of any flood defences in the area. These defences reduce, but do not completely stop, the chance of flooding as they can be overtopped, or fail.
Flood risk from Surface Water:	Very Low Risk
Description of Risk:	Very low risk means that this area has a chance of flooding of less than 0.1% each year. Flooding from surface water is difficult to predict as rainfall location and volume are difficult to forecast. In addition, local features can greatly affect the chance and severity of flooding.
Flood risk from Reservoirs:	Unlikely (Low)
Description of Risk:	Flooding from reservoirs is unlikely in this area. An area is considered at risk if peoples' lives could be threatened in the event of a dam or reservoir failure.
Flood risk from Groundwater:	Possible (Medium)
Description of Risk:	Flooding is possible in the local area when groundwater levels are high. This is due to the site resting on permeable ground in which the water table can rise to flood below ground structures such as basements. Under very wet (often prolonged) conditions the water table could rise above ground level causing standing water in low lying areas.

Table 3: Flood Designation

Based on the flood risk status above, the site this Assessment provides the following guidance:

The overall flood risk for this site is assessed as being HIGH; boreholes should always be sealed with grout over at least the top 10 metres below ground level

and chambers for manifolds, etc, should be positioned to avoid them becoming flooded, they should be sealed and if possible raised.

5.2 Hydrogeology

In this section the ground beneath the site is divided into hydrogeological units which are in turn considered in terms of the presence, abundance, movement and issues and water resource considerations. Each unit is considered as it is reached with depth below the site.

The study has considered the different strata present beneath the site in terms of their hydrogeological conditions. Where there are no boreholes or abstractions locally which can be used directly to characterise the ground, BAHS Ltd use information derived from representative abstractions completed into comparable hydrogeological settings.

Hydrogeological Unit(s): Soil & shallow Chalk horizons -
Dry & Weathered

Hydrogeological Description: N/A

RWL: N/A

T range: N/A

Comments:

The shallow ground is dry or only seasonally wet following periods of rainfall and/or times of high river levels. At all other times the shallow ground is unsaturated.

Hydrogeological Unit(s): New Pit & Holywell Nodular Chalk
Formations

Hydrogeological Description: Principal Aquifer

RWL: 80 to 85 maOD

T range: >20 m²/day

Comments:

These Chalk Formations represent a Principal Aquifer which is targeted heavily for groundwater abstraction. Groundwater is present primarily in joints and fractures that dissect the limestone. There is rapid groundwater movement through these layers which would help to disperse the thermal influence of a GSH system drawing from closed loop boreholes.

Hydrogeological Unit(s): Zig Zag & West Melbury Marly Chalk
Formations

Hydrogeological Description: Secondary A Aquifer(s)

RWL: 80 to 85 maOD

T range: 10 to 30 m²/day

Comments:

These Chalk Formations are less transmissive and more marly than the shallower Chalk layers. Groundwater is still mainly found in joints and fractures, but these are fewer, smaller and less well connected. Groundwater flow is therefore less and slower.

Hydrogeological Unit(s): Upper Greensand

Hydrogeological Description: Principal Aquifer

RWL: 80 to 85 maOD

T range: Up to 20 m²/day

Comments:

The Upper Greensand is fully saturated with groundwater mainly found in pore spaces. As the unit is not very well consolidated, few joints and fracture pathways are able to develop. There is little and only slow movement of groundwater.

Hydrogeological Unit(s): Gault Clay

Hydrogeological Description: Aquitard

RWL: N/A

T range: N/A

Comments:

The low permeability of the Gault Clay Formation serves to retain water in the overlying layers and to confine the deeper layers, separating groundwater above and below from each other.

Hydrogeological Unit(s): Lower Greensand & Portland Stone

Hydrogeological Description: Secondary A Aquifers

RWL: N/A

T range: N/A

Comments:

The Lower Greensand and Portland Stone Formations are fully saturated with groundwater found in pore spaces as well as joints and fractures. There is little movement of groundwater as there are no natural outflow points and thus groundwater is almost stationary.

Hydrogeological Unit(s): Kimmeridge Clay

Hydrogeological Description: Aquitard

RWL: N/A

T range: N/A

Comments:

The low permeability of the Kimmeridge Clay Formation serves to retain water in the overlying layers and preventing deeper, inferior groundwater from rising/mixing with shallower groundwater.

6 Hydro-Thermogeological Risk Assessment

6.1 Overview of Subsurface Conditions

The proposed closed loop GSH&C system will penetrate the following geological units:

- Soil and Alluvium deposits (up to 4 metres): Dry unconsolidated materials, mainly soils overlying fluvial sediments.
- New Pit & Holywell Nodular Chalk Formation (31 to 34 metres): Weathered surface passing into firm limestones
- Zig Zag Chalk Formation (25 to 27 metres) & West Melbury Marly Chalk Formation (44 to 47 metres): firm limestones in hydraulic connection with the shallower Chalk layers.
- Upper Greensand Formation (42 to 48 metres): Weakly consolidated, poorly cemented sandstone also in hydraulic continuity with the overlying Chalk layers.
- Gault Formation (25 to 45 metres): stiff blue clays
- Lower Greensand Formation (1 to 12 metres): moderately well consolidated sandstones.
- Portland Group (10 to 15 metres): firm sandstones with interbedded sandstones and limestones.
- Kimmeridge Clay Formation (100 to 120 metres): firm silty clay/mudstone.

6.2 Identified Risks

6.2.1 Contaminated Land

There is a low risk of encountering contaminated ground when excavating the ground around the drill positions, manifold chambers and the routes between the boreholes and the individual buildings. The site is not reported to have been used for industrial or other purposes that might have left a contamination legacy.

6.2.2 Soil & Habitat Disruption

The risk posed to the soil, ground conditions and local ecosystems is considered as a result of proposed drilling and ongoing presence of the closed loop GSH system. Some soil must be removed to drill the boreholes, otherwise the footprint of each borehole is very small (<150mm in diameter). Drilling and ground works will not extend beyond the drilling area; the depth of the boreholes is limited to c.120 metres.

6.2.3 Groundwater Conditions & Grouting

Groundwater within all of the aquifer layers below the site, are assessed to have groundwater levels that would settle below ground level. There is thus no risk identified from artesian groundwater conditions or from the movement/migration of groundwater.

6.2.4 Groundwater Quality & Temperature

Groundwater within the Chalk and the deeper Greensands are both of good quality with no reported contamination locally. Drilling would pass through all of the Chalk Formations present and terminate at 120 metres within the Upper Greensand Formation. All of these hydrogeological units are already in hydraulic continuity and thus a borehole passing through them would not change the hydraulic situation or should not change the quality of groundwater present. The presence of ground loops, used to recover heat from the ground, are considered in the context of whether they may pose a risk to ground/groundwater temperatures.

6.2.5 Borehole Stability

Weakly consolidated units and minor solution features pose [from] a low risk of borehole wall collapse, especially during prolonged or paused drilling and until the pipework is installed and grouted in position. The Upper Greensand may be found to be weakly cemented, however drilling with a thickened mud will normally hold the sands in place allowing completion to depth and installation of the ground collector loops. The risk posed to the scheme is therefore low and there is no/low risk posed to the environment.

6.2.6 Noise and Vibration

There is a low risk of disturbance, nuisance and damage resulting from the drilling of any borehole. The associated risk is posed to the operator(s) of the equipment, neighbours, the surrounding environment and habitat.

6.3 Mitigation Measures & Considerations

6.3.1 Contamination

- During excavation of shallow ground, signs of contamination would be reported and works paused to confirm and deal with anything found. Boreholes shall be commenced with a trial pit to a depth of up to 1.2 metres to check for services/utilities and for any signs of contamination.

- The drilling rig will have been serviced and well maintained prior to mobilisation to site. No servicing or works shall be undertaken on the rig while it is on site to avoid any risk of oil, fuel or loss of other contaminants to ground.
- Fuel shall not be stored on site for the drilling rig and associated equipment. Fuel shall only be brought to site when needed, stored on spill trays with spill kits and removed when no longer needed. Refuelling on site will be avoided wherever possible.
- Rigs are only used on clean sites and thus there is no risk of transporting contamination to the site.
- Only food grade drilling lubricants and environmentally friendly products are used in the drilling process.

6.3.2 Soil & Habitat

- The risk posed to the soil and wider habitat(s) (land and water), may arise during the drilling/installation of the closed loop boreholes, and/or after, once commissioned and in regular use. During drilling the contractor shall prevent the loss of any drilling muds/fluids from the drilling process from entering the environment. All shall be processed and removed from site on completion along with the drill cuttings. Careful drilling and control of the process as always demonstrated by the contractor, minimises disruption and contains the arisings from the boreholes to within a metre or two of the hole. On completion the arisings/cuttings are cleared away leaving the original ground.
- Once the ground collector loops are installed, they are grouted into the drilled hole to seal them in place. This means that during operation the loops are contained within a low permeability grout. This protects the loops and also prevents any leaks [of food grade antifreeze] as the loops are encased in the low permeability grout material. There is thus no threat posed or risk to the environment.
- By drilling boreholes at a small diameter, the grout surrounding the closed loop boreholes shall be limited to a narrow (c.150mm) column of low permeability ground extending down to a depth of 120 metres. These narrow columns represent a very small fraction of the ground within, and through, which groundwater moves. Their limited number and presence mean the boreholes would have no impact on groundwater presence, quantities or movement or any habitats dependant on groundwater.
- The boreholes shall be installed away from the River Avon, avoiding any hydraulic interaction during drilling and as stated above, the limited diameter and radial influence of the grout mean the boreholes will have no influence on the River long term.

6.3.3 Grout Specification

- Low permeability grout shall be used to seal the boreholes to guard against any future leaks.
- Grouting of the boreholes means no surface water can migrate down the boreholes to the water table.
- Only inert, industry approved, grout shall be used to seal the boreholes.

6.3.4 Groundwater Quality & Temperature

- The quality of groundwater present shall be monitored by the contractor during drilling to confirm the water is of good quality, avoid the loss or drilling fluids into the local environment and to prevent contamination of surface water and groundwater by ensuring best practice is followed at all times. Groundwater with depth, is already in hydraulic continuity with each layer, grouting of the boreholes on completion will maintain any stratification present.
- Thermal modelling of the proposed scheme has informed the closed loop ground collector design so that the heat recovered is sustainable; the amount of heat to be removed is replaced by solar radiation annually. Ground temperatures will not drop below c.5 degrees centigrade in the natural ground immediately around the boreholes during the winter, moving away from the boreholes natural ground temperatures are reached within 3 to 6 metres of the boreholes, representing the permanent maximum radial extent/influence of the installation. Ground temperatures will fully recover annually within the ground 3 to 6 metres of the closed loop boreholes.
- The design is for there to be no thermal influence from the system off site, as the scheme is designed to recover all of the heat potential needed within a radius of 3 to 6 metres around each borehole. Thermal recharge originating from solar thermal radiation over each year.
- There would be no thermal influence on the River Avon or any habitats near or surrounding the site.

6.3.5 Borehole Construction & Ground Stability

- Temporary casing (circa 6 to 7 inch in diameter) shall be used to line the top sections of the boreholes. This will contain the influence of drilling and prevent there being any influence outside of the casing on the ground and surrounding environment.
- The boreholes shall be drilled with clean water, compressed air or a combination. The driller shall seek to recover all drill cuttings from the borehole with minimal loss of drill fluids into the ground
- Drilling shall not remove any more material than that through which the borehole passes and thus will not undermine or cause subsidence, slumping or

collapse of the ground. The grout seal means there would be no future movement of groundwater and thus no erosion or displacement of the ground in the future.

6.3.6 Noise and Vibration Management

- The drilling rig to be used on this site is one of the latest generations of rigs which generates a noise equivalent to heavy goods vehicle or an excavator. The noise most of the time is from the engine which is mainly running in idle and peaks when drilling rods are being advanced through hard(er) ground. In this geology the rig is not expected to struggle as the ground is firm but not excessively hard. Thus the noise and any vibration would not be any greater than that from an excavator working.
- Vibration from the drilling is very rapidly absorbed and dissipated within the ground. Immediately around the drilling rig there would be some minor vibration felt, beyond 5 to 10 metres no vibration would be detected.

6.3.7 Regulatory Compliance

- Ensure boreholes are fully sealed and grouted.
- Maintain required separation distances from sensitive receptors.
- Follow British Standards and GSHP Association guidelines.

6.4 Summary

The proposed drilling and installation of closed-loop ground source heat (GSH) boreholes present generally low environmental and operational risks, with no significant concerns identified regarding contaminated land, soil or habitat disruption, groundwater quality, groundwater movement, or borehole stability. Boreholes are narrow and shallow relative to the surrounding geology, and all aquifer layers are already hydraulically connected, meaning drilling will not alter groundwater conditions. Potential risks, such as soil disturbance, noise, vibration, and minor instability in weak geological layers, are mitigated through strict construction controls, including the use of clean drilling practices, temporary casing, low-permeability grout, environmental protection measures, and careful management of drilling fluids.

Thermal modelling confirms that heat extraction will remain sustainable, with temperature effects confined within 3 to 6 metres of each borehole and no impact on the River Avon or nearby habitats. Additional safeguards include monitoring groundwater quality, avoiding contamination during works, maintaining well-serviced equipment, and complying with relevant industry standards and guidance.

7 Water Quality

The quality of groundwater present beneath the site cannot be accurately predicted without drilling an abstraction borehole and collecting samples for analysis. Sampling and analysis of a water sample from a local borehole drawing from the same geological horizon could provide a good indication of the likely quality of water that may be encountered.

BAHS sample, and test, water quality from boreholes and wells across the United Kingdom and have built up an extensive database of results. Test results from the closest comparable boreholes, wells and springs to the site assessed are provided in the table below. These results can only be used as an indication of the possible quality of water present beneath the site. UK values are the Drinking Water Standards defined by relevant regulations and standards.

Parameters	Concentrations Measured Locally				UK Limit	Unit	Over Limit
	Min	Max	Average	Median			
Alkalinity	41	to 89	65	65	-	mg/l	
Aluminium		<20	-	-	200	µg/l	
Calcium	27	to 112	72	80	-	mg/l	
Chloride	2	to 97	35	15	250	mg/l	
Chromium		<30	-	-	50	µg/l	
Copper	100	to 555	354	380	2000	µg/l	
Cyanide		<10	-	-	50	µg/l	
Fluoride		<450	-	-	1500	ug/l	
Total Iron (FeII+FeIII)	36	to 634	343	351	200	µg/l	*
Lead		<1	-	-	10	µg/l	
Magnesium	3	to 68	20	6	-	mg/l	
Manganese	5	to 5	5	5	50	µg/l	
Nitrate	16	to 40	28	28	50	mg/l	
Nitrite		<15	-	-	500	µg/l	
Phosphate		<0.05	-	-	-	mg/l	
Potassium	2	to 8	5	7	-	mg/l	
Sodium	7	to 181	64	19	200	mg/l	
Sulphate	11	to 47	33	40	250	mg/l	
Sulphide		<0.1	-	-	-	mg/l	
Zinc		<0.2	-	-	-	mg/l	
Electrical Conductivity	460	to 557	506	504	2500	µS/cm	
Hardness, Total, as CaCO ₃	69	to 279	199	224	-	mg/l	
pH	6.9	to 7.5	7.1	7.1	6.5-9.5	pH units	
Total Dissolved Solids	253	to 306	279	277	-	mg/l	

Table 4: Indicative water quality

The above provides an indication of the likely quality of groundwater present in the Chalk and the Upper Greensand combined. The quality is shown to be good with only raised iron levels, there is no risk anticipated from drilling into/through groundwater and from any mixing or movement of groundwater.

8 Thermogeology

It is unlikely that any of the geological units beneath the site have a sufficient thickness to individually sustain the planned closed loop ground source heating system. Any new system developed at this site will operate using one or more boreholes drilled through a number of horizons. For this reason, this section considers the thermal properties of each unit individually and then provides estimates of the bulk average thermal properties of the ground for different drill depths.

The geology beneath the site to a depth of over 200 metres is divided in to 11 thermogeological units based on lithology, weathering and saturation. Table 5 summarises the thickness and the thermal properties of each horizon. The values within this table have been derived from field measurements, laboratory tests and published results. Some of the ranges of thermal values are wide, which reflect natural variabilities within the thermogeological unit.

The wider the thermal value range, the more important it is for closed loop designs to be revised to reflect confirmed ground conditions during installation. On large projects a thermal response test may be considered if the range of thermal values is wide, as such testing accurately confirms actual thermal values across the final drill depth.

Strata Name/Unit Description	Maximum thickness (metres)	Thermal Conductivity (W/mK)			Volumetric Heat Capacity (MJ m ⁻³ K ⁻¹)		
Alluvium - Unsaturated	4	0.60	-	0.90	1.70	-	1.90
New Pit & Holywell Nodular Chalk Formations - Putty Chalk - Unsaturated	1	1.50	-	1.75	1.80	-	2.00
New Pit & Holywell Nodular Chalk Formations - Putty Chalk - Saturated	9	1.70	-	2.00	2.20	-	2.30
New Pit & Holywell Nodular Chalk Formations	24	1.80	-	2.45	2.20	-	2.30
Zig Zag Chalk Formation - Fractured & Jointed	27	2.79	-	2.89	2.10	-	2.20
West Melbury Marly Chalk Formation	47	2.15	-	2.35	2.05	-	2.15
Upper Greensand Formation	48	2.57	-	2.67	2.00	-	2.10
Gault Formation	45	1.98	-	2.08	2.25	-	2.35
Lower Greensand Formation	12	2.54	-	2.64	2.00	-	2.10
Portland Group	15	1.70	-	2.30	2.05	-	2.2
Kimmeridge Clay Formation	120	1.4	-	1.65	2.35	-	2.45

Table 5: Table of thermal properties

Table 6 below lists the thermal conductivity and volumetric heat capacity of the ground for different drill depths.

Drill Depth	Thermal Conductivity			Volumetric Heat Capacity			Thermal Diffusivity		
(Metres)	(W/mK)			(MJ m-3K-1)			(msq/day)		
50	1.92	-	2.34	2.13	-	2.24	0.074	-	0.095
55	2.00	-	2.39	2.13	-	2.23	0.077	-	0.097
60	2.06	-	2.43	2.12	-	2.23	0.080	-	0.099
65	2.12	-	2.46	2.12	-	2.23	0.082	-	0.100
70	2.12	-	2.46	2.12	-	2.22	0.082	-	0.100
75	2.12	-	2.45	2.11	-	2.22	0.083	-	0.100
80	2.12	-	2.44	2.11	-	2.21	0.083	-	0.100
85	2.13	-	2.44	2.10	-	2.21	0.083	-	0.100
90	2.13	-	2.43	2.10	-	2.21	0.083	-	0.100
95	2.13	-	2.43	2.10	-	2.20	0.083	-	0.100
100	2.13	-	2.42	2.10	-	2.20	0.084	-	0.100
105	2.13	-	2.42	2.09	-	2.20	0.084	-	0.100
110	2.13	-	2.42	2.09	-	2.20	0.084	-	0.100
115	2.14	-	2.42	2.09	-	2.19	0.084	-	0.100
120	2.16	-	2.43	2.09	-	2.19	0.085	-	0.101
125	2.18	-	2.44	2.08	-	2.19	0.086	-	0.101
130	2.19	-	2.45	2.08	-	2.18	0.087	-	0.102
135	2.21	-	2.46	2.08	-	2.18	0.087	-	0.102
140	2.22	-	2.47	2.07	-	2.18	0.088	-	0.103
145	2.23	-	2.47	2.07	-	2.17	0.089	-	0.103
150	2.24	-	2.48	2.07	-	2.17	0.089	-	0.104
155	2.25	-	2.49	2.07	-	2.17	0.090	-	0.104
160	2.26	-	2.49	2.06	-	2.17	0.090	-	0.104
165	2.25	-	2.48	2.07	-	2.17	0.090	-	0.104
170	2.25	-	2.47	2.08	-	2.18	0.089	-	0.103
175	2.24	-	2.46	2.08	-	2.18	0.089	-	0.102
180	2.23	-	2.45	2.08	-	2.19	0.088	-	0.101
185	2.23	-	2.44	2.09	-	2.19	0.088	-	0.101
190	2.22	-	2.43	2.09	-	2.20	0.087	-	0.100
195	2.21	-	2.42	2.10	-	2.20	0.087	-	0.100
200	2.21	-	2.41	2.10	-	2.20	0.087	-	0.099
205	2.20	-	2.40	2.10	-	2.21	0.086	-	0.099
210	2.21	-	2.41	2.10	-	2.20	0.087	-	0.099
215	2.21	-	2.41	2.10	-	2.20	0.087	-	0.099
220	2.21	-	2.41	2.10	-	2.20	0.087	-	0.099
225	2.20	-	2.41	2.10	-	2.20	0.086	-	0.099
230	2.19	-	2.41	2.10	-	2.20	0.086	-	0.099
235	2.18	-	2.40	2.10	-	2.20	0.085	-	0.099
240	2.16	-	2.38	2.10	-	2.21	0.084	-	0.098
245	2.14	-	2.37	2.11	-	2.21	0.084	-	0.097
250	2.13	-	2.35	2.11	-	2.22	0.083	-	0.096

Table 6: Bulk average thermal properties over different drill depths

The thermal conductivity initially increases from a depth of 50 metres to a peak value of 2.378 W/mK at a depth of 160 metres. Subsequently, it decreases to a minimum value of 2.241 W/mK at a depth of 250 metres. The volumetric heat capacity decreases as depth increases. The values in the table show that the thermal diffusivity initially increases from a depth of 50 metres to a depth of 160 metres, peaking at 0.0973 m²/day, and then decreases gradually until a depth of 250 metres, reaching a value of 0.0896 m²/day.

These values should be recalculated to reflect the actual thickness and lithological characteristics of the ground once proven by the driller after completion of the first one or two holes.

The values listed above should be used to develop a model to design and then simulate the performance of the borehole collectors for a ground source heating system at this site. The average ground temperature at the site between ground level and 200 metres depth based on published values is 10.39 degrees Centigrade.

BAHS have been measuring ground temperatures around the UK for over 20 years, based on this data set, the average ground temperature between ground level and 200 metres depth below this location is estimated to be 11 to 12 degrees.

Generally ground temperatures are higher than reported values, however BAHS and other designers of GSH borehole arrays should use the published values [for compliance with Professional Indemnity insurances] until site-specific measurements can be made. Once confirmed by measurements, higher ground temperatures will normally enable a smaller borehole array to be installed and/or a more efficient system to be developed.

The heat originating in the centre of the earth is true geothermal energy, only a very small amount of heat in the shallow ground below a site (down to several hundred metres) has geothermal origins, the vast majority originates from solar thermal recharge. The geothermal component is measured as a background warmth rising up to the earth's surface, this is known as the geothermal heat flux which varies across the earth's surface.

While the influence of the geothermal heat flux is small and not a large factor in the overall design of most ground source heating collectors (+/-2.5%), on large borehole arrays this influence can be more significant and effect the number of boreholes needed. The British Geological Survey (BGS) have been measuring and calculate the geothermal heat flux for many years and publish the following map of thermal values.

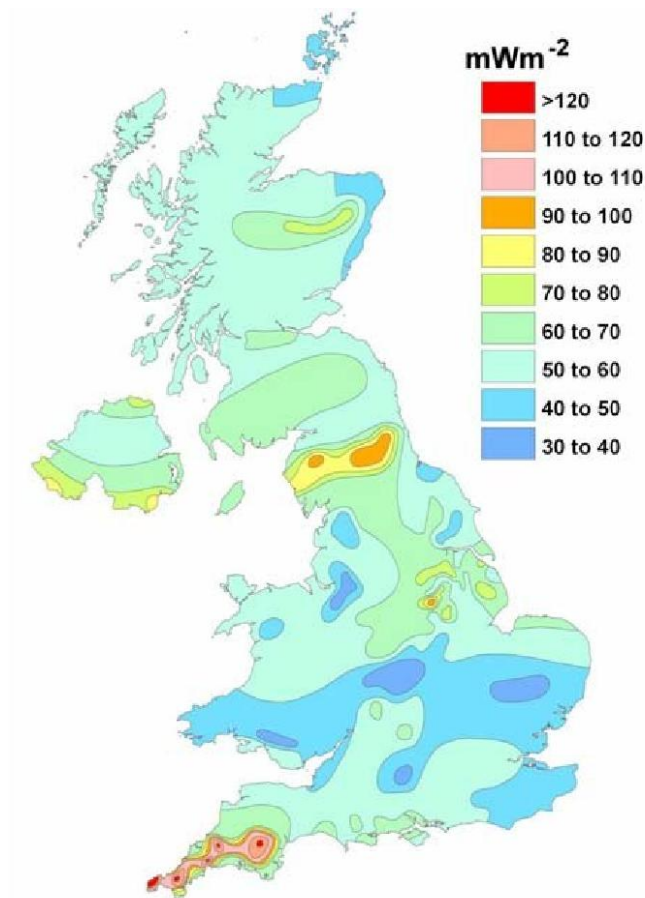


Figure 3: BGS Geothermal Heat Flux Map

BAHS have been measuring geothermal heat flux for at least 17 years across the UK, these values complement and expand the BGS dataset. The BGS map indicates the geothermal heat flux beneath the site is in the order of 50 to 60 mW/m^2 , BAHS' measured values close to this site indicate a value of 30 to 40 mW/m^2 . The BGS values should be used when modelling the geothermal contribution, unless site-specific measurements are made as part of a thermal response test.

Groundwater is anticipated to flow towards the south beneath the site. Groundwater flow can have the effect of transporting chilled or warmed water in the same direction. Where possible boreholes should be configured to avoid shadowing as passing groundwater is chilled or warmed.

For example, a line of boreholes, or a grid of boreholes should have their long axis perpendicular to groundwater flow. Any closed loop boreholes drilled at the site should also be separated by an adequate distance determined by careful design, in order to minimise thermal interaction over the lifetime operation of the ground source heating system.

9 Regulatory Considerations

9.1 Licensing

In England the Environment Agency (EA), and Natural Resources Wales (NRW) in Wales, have assessed the available surface water and groundwater resources within each river and groundwater management unit (catchments). The status of each unit or catchment is documented in a corresponding Catchment Abstraction Management Strategy (CAMS). Some of the units have been assessed as having water available, which means that the EA or NRW will consider an application for a licence to abstract surface or groundwater, on a case-by-case basis, dependent on the effects of the new abstraction on other existing abstractors and the environment, in the vicinity.

Other units may be deemed as either over abstracted or over licensed, and there is an over-arching stance in these areas that applications for consumptive groundwater abstraction licences would be refused under these CAMS policies. There are, however, some circumstances where licences may be granted for abstraction at certain times of the year, dependent on hydrological conditions, and possible restrictions imposed on the licences. Applications for licences for open loop ground source heating systems may be considered in all surface water and groundwater units providing the water will be returned to the source and there would be no detrimental effects arising from the proposal.

There is a different system in Scotland operated by the Scottish Environment Protection Agency (SEPA). The following forms a guide taken directly from SEPA publications, with interpretation by B. A. Hydro Solutions Ltd. Boreholes and wells come under the Controlled Activity Regulations (CAR) and their further amendments. It is up to the client or their approved representatives to seek authorisation from SEPA and must prove that any abstraction is sustainable and is not detrimental to the local environment.

Boreholes abstracting less than 10 cubic metres per day will fall under the General Binding Rules and are considered low risk to the environment and do not require registration.

A borehole drawing between 10 and 50 cubic metres per day requires registration, which will require an application to SEPA and incur a fee. A borehole abstracting between 50 and 2000 metres cubed per day would require a simple licence and an abstraction of over 2000 metres cubed per day would require a complex licence. A licence depends on the identification of a responsible person, who must ensure compliance with the conditions of the licence. An application charge will apply, and the activity may also be subject to an annual subsistence charge.

As this Appraisal is concerned with a planned closed loop ground source heating system, there would be no groundwater abstraction.

9.2 Source Protection Zone(s)

Source Protection Zones (SPZs) indicate the presence of sensitive licensed groundwater abstractions from the underlying aquifer(s), often those used for public/private potable supply. The EA and NRW use these zones in conjunction with their Groundwater Protection Policy (GP3) to set up pollution prevention measures in areas which are at high risk, and to monitor the activities of potential polluters nearby that may result in contamination of these sources.

Is site within a SPZ:	No
SPZ number:	N/A

Table 7: Source Protection Zones

Based on the SPZ status beneath the site, this Assessment provides the following guidance:

Although this site is not within a Source Protection Zone, a new borehole should be correctly grouted, headworks sealed and any activities that could pose a risk of contamination must be excluded from around the borehole. For example no soakaways, chemical stores, heating oil storage, septic tanks, etc., within 50 metres of the borehole, and no livestock kept within 20 metres of the borehole.

9.3 Permitting

The EA are moving most regulated activities to a permit-based system which will include abstraction licenses. At present permits are needed for certain activities in close proximity to watercourses and/or where there is a release to the environment. This can include soakaways, direct and indirect discharges to groundwater, open loop ground source heating/cooling systems and drainage activities. It may be possible to avoid a formal permit by ensuring compliance with general binding rules, please refer to the EA, NRW or SEPA websites.

Ground source heating and cooling systems shall be covered by a permitting system with exemptions where compliance with general binding rules can be achieved. The definition of ‘pollutant’ in the Groundwater Directive 2006/118/EC meant that heat in ground was not regulated in the UK. Prior to the Groundwater Directive, heat was considered a pollutant in the ground. The changes to the EPR regulations reinstate heat as a pollutant in ground.

The EA do not consider that heat from closed loop boreholes is one of the significant sources of heat which could pose a risk to the environment; and so are putting in measures to reduce the burden to the GSHP community as much as possible.

Projects that comply with the following binding rules should not need to notify and would not need a permit from the EA. Rules and conditions may change between issue of this report and drilling, therefore BAHS recommend seeking clarification prior to drilling. The rules at the time of drilling are summarised below with an assessment of compliance:

Closed Loop GSHP Permit Exemption Criteria	Can this system comply: Yes/No	Minimum Distance from site to... (metres)
The system must be fully sealed, i.e. grouted:	YES	N/A
The installation must not mobilise contamination to cause pollution of surface water or groundwater:	YES	N/A
The scheme cannot place a closed loop system adjacent to a septic tank or cesspit:	YES	N/A
Not within the inner zone of a source protection zone, SPZ 1:	YES	N/A
Not within 250 metres of protected sites (e.g. SSSI) or ancient woodland; with some exceptions:	NO	<50
Not within 50 metres of a well, spring or borehole supplying water used for domestic or food production:	YES	200
All equipment used must comply with British Standards and Ground Source Heat Pump Association Standards:	YES	N/A
Eventual decommissioning must not cause a risk of pollution.	YES	N/A

Table 8: Permit exemption criteria

Based on the above, this Assessment concludes that a development at this site could not comply with the binding rules. The Environment Agency have been consultant by others, and it is reported that a permit is not required.

9.4 Mining Remediation Authority Reporting & Permitting

Where a site is underlain by coal bearing strata and strata termed Coal Measures, a Mining Remediation Authority (MRA) Report (formerly known as the Coal Authority (CA)) is recommended to determine whether there are any known mine workings or shafts on or beneath the property. This report will also inform whether a permit to drill is needed to complete the planned drilling work.

This site is not within a Coal Mining Reporting Area. There is therefore no reason to contact the Mining Remediation Authority (MRA), formerly known as the Coal Authority (CA) and a permit to drill from the MRA is not needed.

9.5 Bylaws

There are some local bylaws which prohibit or limit drilling within certain areas. This Assessment cannot provide a definitive list of bylaws, if any may exist that could affect activities on the site, the LA should be consulted in advance of drilling works.

BAHS are not aware of any bylaws that apply to groundwater abstractions/drilling in this area. When consulting with local drilling contractors BAHS recommend raising this with them and/or checking with your Local Authority or planning department.

9.6 Borehole Registration

There is a requirement under the Water Resources Act 1991 (as amended by the Water Act 2003) that boreholes are registered with the British Geological Survey and the Environment Agency. Please find a registration form at the end of this report for use once your borehole has been completed, alternatively registering the borehole(s) can be delegated to your drilling contractor.

10 Geological & Drilling Hazards

The following table summarises the primary geological and drilling hazards this Assessment has identified in the research and production of this document. While every effort has been made to capture all possible risks, drilling boreholes is always challenging and thus it is impossible to foresee and avoid all risks. There can be no guarantee that drilling will be successful, although preparation and careful design should reduce the risk significantly and/or allow an informed decision to drill. See notes in Additional Information 1 at the end of the report.

Drilling Issues:	Geological Unit:	Alluvium	New Pit & Holywell Nodular Chalk Formations	Zig Zag Chalk Formation	West Melbury Marly Chalk Formation	Upper Greensand Formation	Gault Formation	Lower Greensand Formation	Portland Group	Kimmeridge Clay Formation
Risk of needing shallow temporary casing		H	M	L	L	L	L	L	L	L
Risk of needing deep(er) temporary casing		L	L	L	L	M	L	L	L	L
Risk of unstable ground too deep to case		L	L	L	L	M	L	M	L	L
Risk of running sand present		L	L	L	L	H	L	H	L	M
Likelihood of artesian groundwater conditions		L	L	L	L	L	L	L	L	L
Likelihood of swelling clays being present		L	L	L	L	L	H	L	L	H
Risk of near vertical joints and fractures		L	M	H	M	L	L	L	L	L
Likelihood of groundwater presence and flow beneath the site		L	H	H	H	H	L	H	H	L
Risk of encountering cavities, voids, caves, etc.		L	L	L	L	L	L	L	L	L
Risk of solution features being present or developing		L	L	L	L	L	L	L	L	L
Likelihood of encountering hard layers/bands which may slow drilling		L	M	M	M	L	L	L	M	L
Risk of subsidence due to drilling		L	L	L	L	L	L	L	L	L
Likelihood of losing flush during drilling		L	M	M	M	M	L	M	M	L
Risk of encountering natural gas (poisonous, explosive, compressed, etc.): risk arises from deeper organic rich layers.		L	L	L	L	L	L	M	H	H
Risk of the ground being affected by landfills (and associated leachate & gases)		L	L	N/A						
Likelihood the site rests on strata that may have been mined		L	L	L	L	L	L	L	L	L
Risk of contaminated land being present		L	L	N/A						
Risk of encountering buried structures, tunnels or other infrastructure		L	L	N/A						
Possibility of unexploded ordnance (this is not a UXO risk assessment)		L	L	N/A						

High	Medium to High Likelihood	Medium	Low to Medium Likelihood	Low	Low Likelihood
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Table 9: Geological & Drilling Hazards

11 Design Risk Assessment

11.1 Project Context

This Design Risk Assessment supports the proposed closed-loop ground source heating system at Littlecott Mill. It evaluates the technical and environmental risks associated with the design, installation, and operation of the ground collector system, with reference to hydrogeological conditions and borehole performance. This section should be read in conjunction with Appendix 1 which provides a tabulated design risk assessment based on which this section has been prepared.

11.2 Key Design Risks and Mitigation Measures

11.2.1 Ground Thermal Performance and Load Matching

Risk: Incorrect heating load projections may lead to ground freezing or overheating, causing ground disturbance and reduced system efficiency.

Mitigation: Thermal response testing completed to validate ground conditions. System designed to operate within the thermal capacity of the borehole array. Ongoing performance monitoring at 6 and 12 months post-commissioning.

11.2.2 Hydraulic and Flow Constraints

Risk: Insufficient flow or excessive pressure in ground loops may reduce heating output.

Mitigation: Pipework designed to minimise pressure losses and ensure balanced flow. Circulation pump appropriately sized. Commissioning to verify flow rates and pressure stability.

11.2.3 Interaction with Unknown Adjacent Systems

Risk: Undocumented neighbouring GSHP systems could interfere with thermal recovery.

Mitigation: Investigations confirm no known adjacent systems. Borehole layout avoids thermal overlap zones.

11.2.4 Ground Collector Integrity

Risk: Leaks or damage to pipework may reduce system performance or cause environmental harm.

Mitigation: Use of low-toxicity heat transfer fluids.

Pressure testing during construction and continuous monitoring during operation. Warning tape installed above pipework to prevent accidental excavation damage.

11.2.5 Biofouling and Fluid Temperature Extremes

Risk: Biofouling may clog heat exchangers; extreme fluid temperatures may damage the ground or system.

Mitigation: Biocide treatment during commissioning. Annual servicing and loop flushing. Temperature monitoring and operational controls to prevent over-extraction or rejection of heat.

11.3 Hydrogeological Considerations

The Hydrogeological Risk Assessment identified several subsurface risks that influence design decisions:

Contaminated Ground: No contaminated ground is expected, but if found it shall be removed or treated. The top section of boreholes shall be steel cased and during drilling, and on completion, the boreholes shall be grouted from ground level to their base, preventing vertical movement of groundwater and/or contamination moving vertically via boreholes.

Groundwater Flow: Groundwater levels and flow in the Chalk and the Upper Greensand shall not be affected by the planned scheme. While boreholes shall be grouted, this represents a very narrow diameter column of ground (c. 150mm diameter and 120 metres deep) which will not affect or influence groundwater flow or levels in the Chalk or the Upper Greensand.

Groundwater Quality: All water bearing units that may be encountered are already in hydraulic continuity with each other, thus there would be no new mixing or change in water quality present.

Borehole/Ground Stability: Weathered and weakly consolidated shallow ground shall require temporary casing during drilling and would be sealed with grout post-installation. Drilling shall not remove any

more material than that through which the borehole passes and thus will not undermine or cause the slumping or collapse of the ground. The grout seal means there would be no future movement of groundwater and thus no erosion or displacement of the ground in the future.

11.4 Summary

The design incorporates multiple layers of risk mitigation, from thermal modelling and hydraulic balancing to environmental safeguards and hydrogeological resilience. Provided that commissioning and monitoring protocols are followed, the system is expected to operate safely and effectively within the constraints of the site's geological and environmental conditions.

12 Assessment Summary

B. A. Hydro Solutions Ltd. has been commissioned to complete a Hydro-Thermogeological Appraisal to characterise the conditions present, quantify the hydro and thermogeological properties for design purposes and to enable the production of a hydrogeological and design risk assessments. This study has collected and assessed all available information at the time of production.

Please refer to:

- Section 3 for geological & structural summary,
- Section 4 for discussion on the lithology beneath the site,
- Section 5 for discussion on the hydrological and hydrogeological setting,
- Section 6 for Hydrogeological Risk Assessment,
- Section 7 for discussion on the anticipated water quality,
- Section 8 for thermogeological properties,
- Section 9 for relevant regulatory information,
- Section 10 for geological and drilling hazards, and
- Section 11 for design risk assessment.

The findings from this study are listed below:

Strata	Thickness (m)	Max Depth (m)
Alluvium	2 to 4	4
New Pit & Holywell Nodular Chalk Formations	31 to 34	38
Zig Zag Chalk Formation	25 to 27	65
West Melbury Marly Chalk Formation	44 to 47	112
Upper Greensand Formation	42 to 48	160
Gault Formation	25 to 45	205
Lower Greensand Formation	1 to 12	217
Portland Group	10 to 15	232
Kimmeridge Clay Formation	>100	>332
HYDROGEOLOGY		
Anticipated rest water level:	80 to 85	maOD
Water Quality Summary:	Good	
Direction of Groundwater Flow:	South	
CLOSED LOOP GSH		
Thermal Conductivity Summary:	The thermal conductivity initially increases from a depth of 50 metres to a peak value of 2.378 W/mK at a depth of 160 metres. Subsequently, it decreases to	

	a minimum value of 2.241 W/mK at a depth of 250 metres.
Volumetric Heat Capacity Summary:	The volumetric heat capacity decreases as depth increases.
Thermal Diffusivity Summary:	The values in the table show that the thermal diffusivity initially increases from a depth of 50 metres to a depth of 160 metres, peaking at 0.0973 m ² /day, and then decreases gradually until a depth of 250 metres, reaching a value of 0.0896 m ² /day.
Long-Term Average Ground Temperature (published values):	10.39 Degrees C
Geothermal Heat Flux (BGS):	50 to 60 mW/m ²

Table 10: Summary table

The investigations undertaken for this Hydro-Thermogeological Appraisal confirm that the proposed closed-loop ground source heating system presents a low environmental risk. The very shallow ground across the site is dry, stable, and shows no evidence of historic contamination, and any unforeseen contamination encountered during construction would be immediately managed under established protocols. As drilling and installation activities occupy only a very small footprint and involve tightly controlled handling of drilling fluids and cuttings, the likelihood of adverse environmental effects is minimal.

Assessment of groundwater conditions confirms that the underlying Chalk and Upper Greensand aquifers are already in natural hydraulic continuity, meaning the passage of boreholes through these strata will not alter groundwater movement or stratification. Each borehole will be fully grouted upon completion, creating a sealed and inert column that prevents leakage of heat-transfer fluid and maintains the natural separation of groundwater horizons. Because the boreholes are narrow (approximately 150 mm diameter), they represent an extremely small proportion of the subsurface and therefore cannot influence groundwater flow, pressure, or quality.

Thermally, the ground conditions at the site are accounted for in the design to arrive at a sustainable closed-loop system. Thermal modelling and the geological assessment confirm that ground temperatures will recover naturally each year, with the zone of cooling confined to approximately 3 to 6 metres around each borehole and no heat influence extending beyond the site boundary. Solar recharge ensures long-term equilibrium, allowing the system to operate efficiently without degrading ground conditions or affecting groundwater temperature. This supports the long-term viability of the installation from both technical and environmental perspectives.

The works required to install the system will generate only minor, short-term disturbance to soils, with no impact on habitats, and local receptors. Boreholes have very small surface footprints, drilling arisings are carefully contained and removed, and reinstatement restores the surface immediately after completion. Noise and vibration levels during drilling are expected to be low, comparable to typical construction plant, and diminish rapidly with distance, with no detectable vibration beyond roughly 5 to 10 metres. These impacts are therefore considered manageable and not significant for nearby properties, ecological receptors, or the surrounding environment.

Finally, the risk of land subsidence is assessed as extremely low, as the drilling process does not remove excess material or create voids, and the final grouted boreholes form stable, solid columns within the ground. Groundwater levels lie below ground level in all water bearing strata, eliminating the potential for artesian uplift or pressure-related ground movement. Combined with engineering safeguards, such as grout sealed boreholes and adherence to British Standards, the system is technically sound and environmentally resilient.

Overall, the project could proceed with confidence, offering a sustainable, low-impact heating solution without posing harm to the environment, groundwater systems, or the stability of the ground. The thermogeology assessed indicates that thermal values peak around to 135 metres below ground level although there is only a small decrease beyond, towards 200 metres depth.

Flooding is possible in the local area when groundwater levels are high. This is due to the site resting on permeable ground in which the water table can rise to flood below ground structures such as basements. Under very wet (often prolonged) conditions the water table could rise above ground level causing standing water in low lying areas. The presence of closed loop boreholes would not influence or change the impact of any such flooding.

The overall flood risk for this site is assessed as being HIGH; boreholes shall be sealed with grout over their full length and chambers for manifolds, etc, shall be positioned to avoid them becoming flooded, they shall be sealed and if possible raised. Although this site is not within a Source Protection Zone, new boreholes shall be grouted, headworks sealed and any activities that could pose a risk of contamination would be excluded from around the borehole.

BAHS are not aware of any bylaws that apply to groundwater abstractions/drilling in this area. When consulting with local drilling contractors BAHS recommend raising this with them and/or checking with your Local Authority or planning department.

This site is not within a Coal Mining Reporting Area. There is therefore no reason to contact the Mining Remediation Authority (MRA), formerly known as the Coal Authority (CA) and a permit to drill from the MRA is not needed.

Projects that comply with binding rules should not need to notify and would not need a permit from the EA. Rules and conditions may change between issue of this report and drilling, therefore BAHS recommend seeking clarification prior to drilling. Based on rules published by the EA at the time of reporting, this site may not comply with the binding rules, however it is reported that the EA have advised a Permit would not be needed.

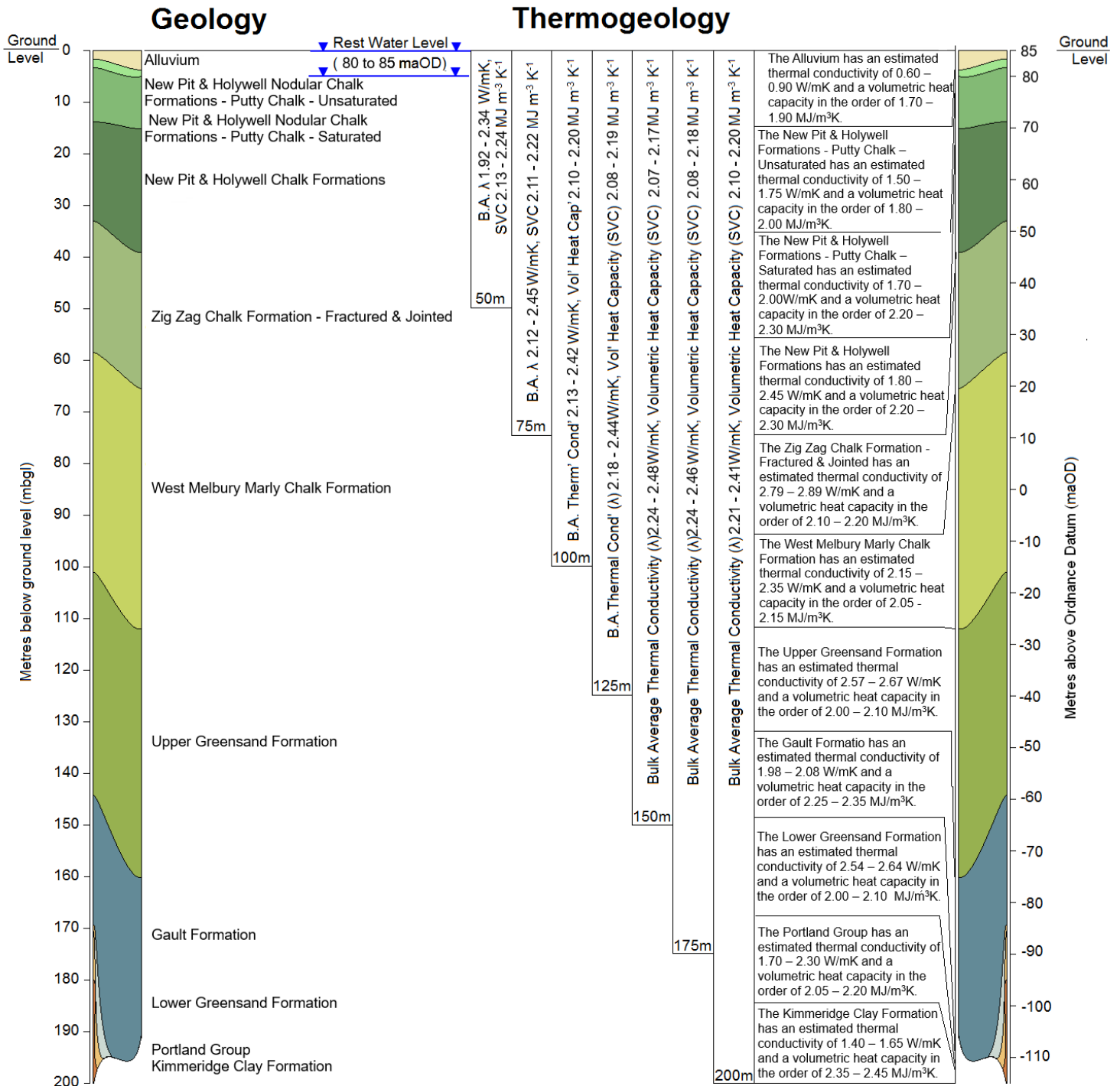


Figure 4: Thermosummary

Disclaimer – Littlecott Mill, Enford Pewsey, Wiltshire, SN9 6AW

The information and analyses provided in this report are based on data and information made available to B. A. Hydro Solutions Ltd. and represent the professional opinions and interpretations of B. A. Hydro Solutions Ltd. This report is prepared with the utmost care based on the current state of knowledge and technology and the data provided by the client along with data specifically collected for this assessment.

B. A. Hydro Solutions Ltd. makes no warranties, expressed or implied, regarding the accuracy, completeness, or utility of the information contained in this report. While we strive to provide accurate and up-to-date information, the conditions of the subsurface environment are inherently variable and complex. As such, B. A. Hydro Solutions Ltd. cannot guarantee that the conditions described in this report will be representative of all areas of the site or that they will remain unchanged over time.

Clients considering the implementation of projects based on findings within this report should be aware that natural conditions, including but not limited to groundwater presence, quantity, and quality, as well as thermogeological and soakaway performance, may not meet expectations. These conditions can vary due to factors beyond our control, including seasonal variations and other external influences not accounted for in this study.

Decisions and actions taken based on this report are the sole responsibility of the client. B. A. Hydro Solutions Ltd. shall not be liable for any direct, indirect, incidental, or consequential damages resulting from the use of this information. Clients are encouraged to engage in further consultation and to conduct additional studies where necessary. This disclaimer applies to this report and any other related documentation provided by B. A. Hydro Solutions Ltd. Use of this report constitutes acceptance of these terms.

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MARCH 2026

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Appendix 1 – Design Risk Assessment Table

Closed Loop Design Risk Assessment

Project Name:	27561463	Persons Affected (P)	Likelihood (L)		Severity (S)	
Project Name:	Littlecott Mill	1	Never likely		Major risk i.e. No or Trivial Loss	
Prepared/Checked By:	Joe McGraw	2	Unlikely to occur		Significant i.e. First Aid, Minor Injury	
Date:	02/01/2025	3	Even chance		Moderate, i.e. RIDDOR reportable	
Version No:	1.0	4	Likely to occur		Major injury i.e. RIDDOR, serious loss	
Title:	Design Risk Assessment	5	Definitely will occur		>1 Major injury, Fatality, etc.	

Risk Ref No.	Hazard	Risk	Risk Ranking (L x S = R)			Revised Risk Ranking			Further Hazard Reduction Measures Needed	Date Completed
			P	L	S	P	L	S		
1	Incorrect quantification of heating load projections	Frosting of the ground resulting in ground disturbance	2.5	2	3	6	2	2	4	Careful commissioning and monitoring with review of performance after 6 months, 12 months and ongoing
2	Insufficient heat recovery potential from ground to satisfy the heating system	Building(s) are too cold	3.5	2	5	10	1	3	3	Careful commissioning and monitoring with review of performance after 6 months, 12 months and ongoing
3	Undocumented pre-existing closed loop ground source heating/cooling system(s) at the site and on neighbouring sites.	Interactions between systems resulting in one or more not being able to function as designed.	2.4,5	3	5	15	2	2	4	Careful commissioning and monitoring with review of performance after 6 months, 12 months and ongoing.
4	Insufficient flow through ground loops	GSH system cannot produce enough heating	3.5	3	5	15	1	3	3	Careful commissioning and monitoring with review of performance after 6 and/or 12 months
5	Excessive pressure	Reduced flow through system and/or GSH system cannot produce enough heating	3.5	3	5	15	1	2	2	Careful commissioning and monitoring with review of performance after 6 and/or 12 months
6	Leak from ground collector	Reduces operation of the system	2.3,5	2	5	10	1	2	2	Monitoring to identify any leaks
7	Leak from ground collector	Release of fluids into the environment	1.2	2	5	10	1	2	2	Monitoring to identify any leaks
8	Borholing within the ground collector	Clogging of filters/heat exchangers, reduction in flow, reduction in heating potential	3.5	3	5	15	1	2	2	Annual service and checks
9	Frosting/low temperature of fluid and Overheating/high temperature of fluid	Reduces operation of the system	3.5	3	5	15	1	2	2	Careful commissioning and monitoring with review of performance after 6 and/or 12 months
10	Frosting/low temperature of fluid and Overheating/high temperature of fluid	Frosting/overheating of the ground resulting in ground disturbance	1.2	3	5	15	1	2	2	Careful commissioning and monitoring with review of performance after 6 and/or 12 months
11	Damage to part(s) of the ground collector	Loss of operation or reduced performance	3.5	3	5	15	1	5	5	Monitoring to identify any leaks

Additional Information 1 – Geological and Drilling Hazards Explanatory Notes

The following discusses the primary geological and drilling hazards that could be encountered. While every effort is made to capture all possible risks, drilling boreholes is always challenging and thus it is impossible to foresee and avoid all risks. There can be no guarantee that drilling will be successful, although preparation and careful design should reduce the risk significantly and/or allow an informed decision to drill. This Assessment has identified, in the research and production of this document, the risks that can be anticipated. See the earlier Geological and Drilling Hazards Table.

Temporary casing is essential to stabilize the ground and prevent collapse, thereby allowing the borehole to reach the required depth. Typically, most boreholes necessitate at least a short section of temporary casing. However, as the depth increases, the casing not only becomes heavier but also more challenging to install and subsequently remove. The removal difficulty arises as the surrounding earth may exert a 'gripping' effect on the casing, necessitating drilling rigs with increasingly robust pull-back capabilities. Installation of temporary casing is therefore a time-consuming process.

The availability of appropriate casing is another consideration; not all contractors possess the necessary casing on hand, and even when they do, the available lengths and diameters may not meet specific project requirements. Drillers must be prepared in advance to ensure preparedness, although unforeseen circumstances may still necessitate additional casing that could not be initially anticipated.

Running sand, a phenomenon where sand and water cascade into a borehole, can occur naturally or be induced by drilling activities. Running sand does not occur in all geologies, it is more common where the ground is formed of sands and weakly cemented sandstones. This issue typically arises due to a flow of water or a disparity in hydrostatic head between the interior and exterior of the borehole, leading to the accumulation of sand within the hole. The situation is analogous to attempting to dig a deep hole on a sandy beach, where the sand and water continually collapse into the hole.

To manage this challenge, methods such as casing or the use of specific drilling fluids are employed. The latter involves adjusting the density and viscosity of the fluids to support the sand-rich walls of the borehole, thereby preventing the ingress and collapse of sand and water. Additionally, a horizon that appears stable can collapse due to running sand if the hydrostatic head inside the borehole drops below that of the surrounding aquifer. Consequently, running sand issues may not be immediately apparent and can emerge as a significant problem during the drilling process. Furthermore, if the sand horizon is not adequately sealed during drilling, running sand can continue to plague the borehole, resulting in the hole filling, sandy ingress to the pump, turbidity, wear on the pump, etc.

Artesian groundwater conditions occur when water within a discrete horizon is under pressure, causing it to rise up a borehole and settle above the ground level from which drilling commences. For groundwater to be classified as artesian, it must be confined beneath a layer of lower permeability or within discrete fracture networks. The recharge area, where rainfall replenishes the groundwater, must be at a higher elevation than the point of drilling. Artesian conditions vary in intensity: weak conditions are characterised by a water level less than one metre above ground and/or a slow flow from the borehole; mild conditions have a water level between one and ten metres above ground and/or a low to moderate flow; strong conditions feature a water level more than ten metres above ground and/or a strong flow.

Managing artesian flow requires designing boreholes with sufficient steel casing in the upper sections to withstand the pressure, capped with a sealing plate. Uncontrolled artesian boreholes, often termed 'wild,' pose significant risks as they waste water, deplete source aquifers, and can harm the surrounding environment. Consequently, allowing an artesian borehole to flow uncontrolled is illegal due to its adverse environmental impacts and resource depletion.

Swelling clays, which are geological layers composed of clay-rich soil that remains plastic due to incomplete hydration, pose significant challenges during drilling operations. As these clays absorb water introduced into the environment through drilling, they expand, encroaching into the borehole space. This expansion is further exacerbated by the unloading of pressure during drilling and the creation of a void, leading to a reduction in the diameter of the drilled hole.

In some instances, this can cause the borehole to contract to the extent that casings and liners may collapse. To manage this issue, it may be necessary to ream the holes to accommodate the installation of casings, ground loops, and other structures. Additionally, swelling clays can cause temporary casings to become stuck, complicating drilling operations. While it is challenging to completely prevent the effects of swelling clays, mitigative strategies such as drilling with a larger initial diameter can be employed to account for potential shrinkage.

Nearly vertical joints and fractures can lead to deviations in drilling trajectories from the intended vertical path. Larger fractures may also lead to partial or complete loss of drilling fluids, which can halt the progression of the borehole. Highly fractured zones are prone to creating unstable borehole walls, potentially leading to collapses or the falling of large blocks of ground into the borehole. Additionally, subsurface voids, caves, and historical workings complicate drilling operations.

These features not only pose stability issues but also complicate the lining and finishing of boreholes. They disrupt the flushing process necessary for clearing drill cuttings, as these cuttings tend to accumulate in the voids rather than returning to the surface. Although sometimes predictable, voids are often encountered unexpectedly, necessitating immediate operational adjustments which can have cost implications, including potential redesigns while the drilling rig and crew incur downtime.

Understanding the presence and flow of groundwater is crucial in the planning and design of new boreholes. Groundwater at shallow depths can complicate drilling operations, particularly when using compressed air techniques. Such conditions often lead to the emergence of large volumes of water that necessitate diversion and management strategies to prevent interference with the drilling apparatus and to maintain safe, manageable working conditions.

The presence of groundwater can significantly affect the dynamics of water flush drilling, potentially leading to the unintended intake or loss of water through permeable strata. This interaction necessitates careful management of drilling fluids to maintain the efficiency and safety of the operation. Moreover, when drilling in aquifers, it is vital to consider the potential impacts on the aquifer to prevent any temporary or permanent reduction in yield or degradation of water quality that could affect local water users.

Solution features pose similar challenges to those discussed around voids, caves, and historical workings; and are associated with zones of high groundwater movement, including the occasional presence of underground rivers. These geological structures can form rapidly in geologies where the host rock is weak, soluble, or susceptible to erosion. Historical solution features pose a risk of inducing sinkholes during drilling activities.

The process of drilling or subsequent groundwater abstraction can lead to ground removal, potentially resulting in void collapses, which may occur sometime after the drilling and not necessarily immediately around or below the borehole. Although rare, there are documented instances globally where a direct link to drilling activities has been established, with many more cases where the link is inferred. Solution features often complicate the completion of boreholes as initially planned. However, if encountered below the water table, they can sometimes yield large quantities of water, thus boreholes should not be immediately abandoned. Proper decommissioning of boreholes is crucial if they are to be abandoned, to prevent further geological hazards.

The loss of drilling fluid, commonly referred to as "losing flush," presents significant challenges. This impedes the return of drilling fluids and cuttings to the surface, which can disrupt the drilling process. The inability to efficiently remove cuttings from the borehole can lead to several complications: the drilling pace slows, the drill head may become clogged, and the drill bit is prone to overheating. The cuttings effectively levitate or float within the rising drilling fluid, they can collapse back into the bottom of the hole once the drilling rods are withdrawn or drilling is paused.

This collapse often fills in the previously drilled depth, preventing the hole from reaching its intended depth. Additionally, the stability of the borehole can be compromised by cuttings that adhere to the hole's walls or lodge within wall pockets. These materials can subsequently collapse into the borehole during drilling or while installing, leading to further difficulties. Such problems require careful management of drilling fluids and strategies to mitigate the risks.

During drilling operations, there is sometimes a risk of encountering natural gas, particularly in areas with historical mining activities, such as coal mining regions. Natural gas accumulations can also originate from organic-rich layers of clay, silt, and mud, or from hydrocarbon-rich strata. The release or mobilisation of gases can be triggered by drilling, chemical processes, increased temperatures or decreased pressure. Oxidation of organic matter in the subsurface can generate gases, along with other less common sources of gases of various types.

Gases pose significant hazards due to their potentially poisonous, explosive, or suffocating nature, and the pressure at which they are found can lead to dangerous blowouts. The hazards are posed not only to the drilling crew but also to nearby humans, animals, and the environment, during and after completion of works.

In regions known for such geological conditions, it is imperative to implement safety measures including gas monitoring and venting, and to avoid the use of compressed air in drilling operations to prevent the migration of gases to adjacent areas. In coal mining areas, obtaining a drilling permit is legally required, which helps manage risks by ensuring appropriate drilling methods are employed. Even in areas where permits are not required, adopting a similar risk assessment approach and developing a suitable drilling methodology is strongly advised where there is any possible risk. Despite thorough risk management, unforeseen gas encounters still occur, necessitating immediate cessation of drilling activities and professional assessment and management of the situation.

Drilling a borehole into or near a landfill site presents significant risks primarily due to the potential release of landfill gas and leachate. Landfill gas, predominantly composed of methane and carbon dioxide, is generated through the anaerobic decomposition of organic waste. If disturbed by drilling, these gases can escape into the atmosphere or accumulate in enclosed spaces, posing serious fire, explosion, and health hazards.

Leachate, a contaminated liquid that percolates through/from waste material, can also be mobilised by drilling activities. This leachate often contains a variety of harmful chemicals and biological agents, which, if released, can contaminate local soil and water bodies, leading to significant environmental and health risks. Therefore, careful risk assessment, monitoring, and management strategies must be implemented when drilling near or into landfill sites to mitigate these hazards effectively, especially historic landfills which may not have been engineered or managed appropriately.

Drilling a borehole in areas that have been previously mined for minerals, salt, coal, or other resources presents significant hazards. Such regions often exhibit increased subsurface instability due to voids and weakened structural integrity resulting from the extraction processes. This can lead to a higher risk of subsidence, where the ground above the voids collapses, potentially causing damage to infrastructure and posing safety risks.

The presence of abandoned mine workings can complicate drilling operations, as encountering unexpected voids or old mine infrastructure can lead to equipment failure or loss, drilling delays, and increased costs. Furthermore, these areas may also be associated with the accumulation of hazardous gases or contaminated groundwater, which can pose environmental and health risks during and after drilling activities. Therefore, thorough assessments and the use of appropriate drilling technologies are crucial to mitigate these risks as well as compliance with permit requirements.

Drilling a borehole in potentially contaminated ground poses significant risks, both environmental and health-related. The primary concern is the mobilisation of contaminants, which can occur when the drilling process disturbs the subsurface environment. This disturbance can lead to the spread of contaminants into previously uncontaminated soil layers or groundwater systems, exacerbating the existing pollution and potentially leading to broader environmental degradation.

There are direct health risks to workers involved in the drilling process, as they may be exposed to hazardous substances released during drilling. Such exposure can lead to acute or chronic health issues depending on the nature and concentration of the contaminants. Furthermore, the introduction of drilling equipment into contaminated zones can lead to cross-contamination, where contaminants adhere to the equipment and are transported to other, previously uncontaminated sites. Therefore, careful assessment and management strategies must be implemented before initiating drilling activities in contaminated areas to mitigate these risks.

Drilling boreholes presents several risks, particularly when encountering below-ground abandoned structures, tunnels, and utilities. These encounters can lead to a range of issues and operational challenges. Drilling into unknown or unmapped structures such as foundations, walls, drains, etc can prevent the progression of boreholes necessitating a move in drill positions and/or damage to drill bits and equipment.

Hitting existing utilities, such as gas lines, water pipes, or electrical cables, can result in utility outages, costly damages, and pose serious safety risks including explosions or electrocutions. Such encounters can lead to significant project delays, increased costs, and legal complications if prior surveys and utility surveys are not conducted thoroughly. Therefore, trial pits should be dug prior to drilling and where appropriate utility mapping is recommended before commencement to mitigate these risks.

Drilling in areas where there could be unexploded ordnance (UXO) presents significant risks, including the potential detonation of explosives, which can lead to severe injury or death of personnel and extensive damage to equipment. To mitigate these risks, comprehensive precautions must be implemented where there is a risk of encountering UXO. Prior to drilling, desk studies should be completed leading on to geophysical surveys to detect the presence of UXO.

Surveys typically involve the use of magnetometers or ground-penetrating radar to identify metallic objects or anomalies beneath the surface. Only trained explosive

ordnance disposal (EOD) professionals should safely remove or neutralise UXO. Where the risk remains despite desk studies and surveys, holes should be progressed by specialist contractors who can use downhole geophysics to check ahead of the drill bit for possible UXO. All drilling personnel should receive specific training on the risks associated with UXO and the protocols for emergency response.

Additional Information 2 – Hydrogeological Terms

The hydrogeological properties of strata and the ground as a whole is a function of its permeability and the ease at which water is able to move through the various strata. The ground can broadly be divided into three hydrogeological rock types, the aquifers which contain water, aquitards which can contain water but restrict the movement of water and aquicludes which do not contain water and act as a barrier to groundwater movement.

Groundwater moves through the ground via either pore spaces in the rocks, fractures and joints which dissect the strata or sometimes through solution features such as caves. The interconnectivity of the pores, joints, fractures and solutions features determines the amount of water which can accumulate and the ability of the ground to transmit.

The storage potential of the ground is described by its *storativity* [S] which is a dimensionless value ranging from zero up to one. The larger the number the greater the proportion of the saturated ground, in terms of total volume, which can be drained by lowering the water table. If the storativity was one it would be space entirely filled with water and no rock.

When the storativity is very low or zero there is no space in which water can accumulate or none of the water in the ground can be abstracted by lowering the water table. Due to the number of observations needed to quantify the storativity of the ground it is uncommon to be able to derive such values from historical data.

The ground's ability to transmit water is measured by its *transmissivity* [T], the larger the number the easier the water is able to move through the rocks. Theoretically there is no maximum T value, practically it is limited by the aquifer thickness, the volume of water in the aquifer and the capacity of the borehole and pump used to test the ground conditions.

The productivity of boreholes is simplistically measured by its *specific yield* [Sy] which is a measure of the sustainable yield a borehole can deliver per day per metre the water table is lowered. This can easily be derived from measurements recorded during pump tests or reported steady state yield and drawdown values.

Additional Information 3 – Borehole Registration Document WR38

WR38: Borehole record form

Borehole record form



**British
Geological Survey**
NATURAL ENVIRONMENT RESEARCH COUNCIL



**Environment
Agency**

Water Resources Act 1991 (as amended by the Water Act 2003)

A Site details

Borehole drilled for _____

Location _____

NGR (ten digits) _____ Please attach site plan

Ground level (if known) _____ metres Above Ordnance Datum

Drilling company _____

Date drilling commenced _____ (DD/MM/YYYY) Completed _____ (DD/MM/YYYY)

B Construction details

Borehole datum (if not ground level) _____ metres (m). Please tick if this is above ☐ or below ☐ ground level.
(point from which all measurements of depth are taken, for example, flange, edge of chamber)

Borehole drilled diameter _____ mm from _____ to _____ m/depth

_____ mm from _____ to _____ m/depth

_____ mm from _____ to _____ m/depth

_____ mm from _____ to _____ m/depth

Casing material _____ diameter _____ mm from _____ to _____ m/depth
and type (for example, if plain steel, plastic slotted). Please record permanent casing details, not temporary casing.

Casing material _____ diameter _____ mm from _____ to _____ m/depth

Casing material _____ diameter _____ mm from _____ to _____ m/depth

Casing material _____ diameter _____ mm from _____ to _____ m/depth

Grouting details _____

Water struck at 1. _____ m (depth below datum – mbd) 2. _____ m (mbd)

3. _____ m (mbd) 4. _____ m (mbd)

C Test pumping summary (Please supply full details on form WR39)

Test pumping datum _____ m. Please tick if this is above ☐ or below ☐ ground level.
(if different from borehole datum)

Pump suction depth _____ mbd

Water level (start of test) _____ mbd

Water level (end of test) _____ mbd

Type of test (for example, bailer, step, constant rate)

Pumping rate _____ m³/hour ☐ or litres/second ☐. Please tick as appropriate.

for _____ days, _____ hours, _____ mins

Recovery to _____ mbd in _____ days, _____ hours, _____ mins
(from end of pumping)

Date(s) of measurements Pump started _____ (DD/MM/YYYY)

Pump stopped _____ (DD/MM/YYYY)

Please supply chemical analysis if available. If you have included this please tick this box ☐

D Strata log

Geological classification (BGS only)	Description of strata	Thickness m	Depth (to base of strata) m
	(continue on separate page if necessary)		
	Other comments (for example, gas encountered, saline water intercepted)		

How long did it take you to fill in this form? |

For Official use only			
Date received (DD/MM/YYYY)	File	Consent number	BGS reference number
Accession number	Wellmaster number	SOBI number	NGR
LIC NO	Purpose		EA reference number
Copy number	Entered by		

WR38: Borehole record form

F The Data Protection Act 1998

The Environment Agency will process the information you provide so that we can:

- deal with your application;
- make sure you keep to the conditions of any consent; and
- process renewals.

The Environment Agency will pass the information provided on this form to the British Geological Survey, in accordance with Section 198 of the Water Resources Act 1991, which states that any person drilling a well or borehole more than fifty feet below the surface, shall notify the British Geological Survey of this and provide them with the information as requested on this form.

We may also process or release the information to:

- offer you documents or services relating to environmental matters;
- consult the public, public organisations and other organisations (for example, the Health and Safety Executive, local authorities, the emergency services, the Department for Environment, Food and Rural Affairs) on environmental issues;
- carry out research and development work on environmental issues;
- prevent anyone from breaking environmental law, investigate cases where environmental law may have been broken, and take any action that is needed;
- assess whether customers are satisfied with our service, and to improve our service; and
- respond to requests for information under the Freedom of Information Act 2000 and the Environmental Information Regulations 2004 (if the Data Protection Act allows).

We may pass the information on to our agents or representatives to do these things for us.

The British Geological Survey will use the information you provide to assist in its geological mapping programme and other research activities.

The British Geological Survey will process, or release, the information to:

- offer you documents or services relating to environmental matters;
- consult the public, public organisations and other organisations (for example, the Health and Safety Executive, local authorities, the emergency services, the Department for Environment, Food and Rural Affairs) on environmental issues;
- carry out research and development work on environmental issues;
- assess whether customers are satisfied with our service, and to improve our service; and
- respond to requests for information under the Freedom of Information Act 2000 and the Environmental Information Regulations 2004 (if the Data Protection Act allows).

We may pass the information on to our agents or representatives to do these things for us.

- We will also publish the information on our website; and
- provide the technical details of the borehole (for example, the depth, geology and water levels) to others. This will not include information about ownership of the borehole.